United States Patent [19]

Zifferer et al.

[11] **3,789,479**

[45] **Feb. 5, 1974**

[54] **MACHINE FOR ASSEMBLING TUBES IN A HEAT EXCHANGER**

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[73] Assignee: **Mordo Company,** Mt. Joy, Pa.

[22] Filed: **June 30, 1972**

[21] Appl. No.: **268,088**

[52] **U.S. Cl.** .... **29/202 R,** 29/157.3 B
[51] **Int. Cl.** **B23p 15/26**
[58] **Field of Search**...... 29/202 R, 202 D, 157,3 B, 29/157.3 R, 208 D, 211 D, 203 D, 200 D

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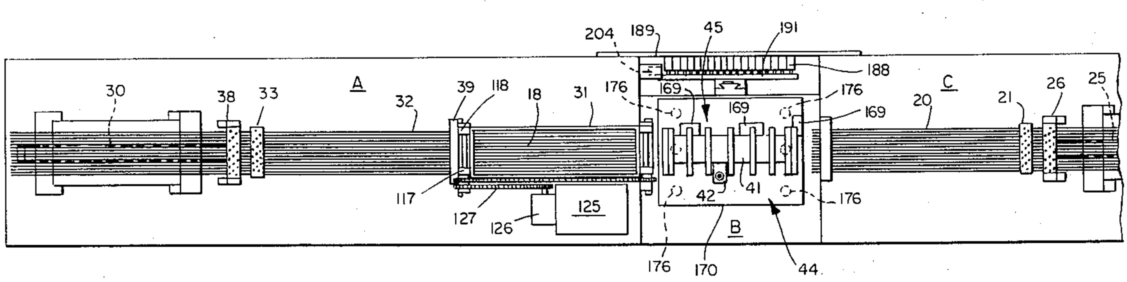
Primary Examiner—Thomas H. Eager
Attorney, Agent, or Firm—Robert B. Frailey

[57] **ABSTRACT**

Machine for assembling automatically the tubes of a shell and tube type heat exchanger having many tubes of uniform length and a plurality of perforated baffle plates through which the tubes pass. A machine is provided having a tube holding fixture mounted on a work table. By means of opposing rods, selected quantities of tubes are transmitted successively from a tube supply to the fixture. Suitable controls are employed to complete one full tubular assembly during each operative cycle of the machine. The tubes are transmitted and assembled in the fixture in a single working plane. Following each deposit of tubes, the fixture is adjusted relative to the working plane preparatory to receiving the next quantity of tubes.

14 Claims, 17 Drawing Figures



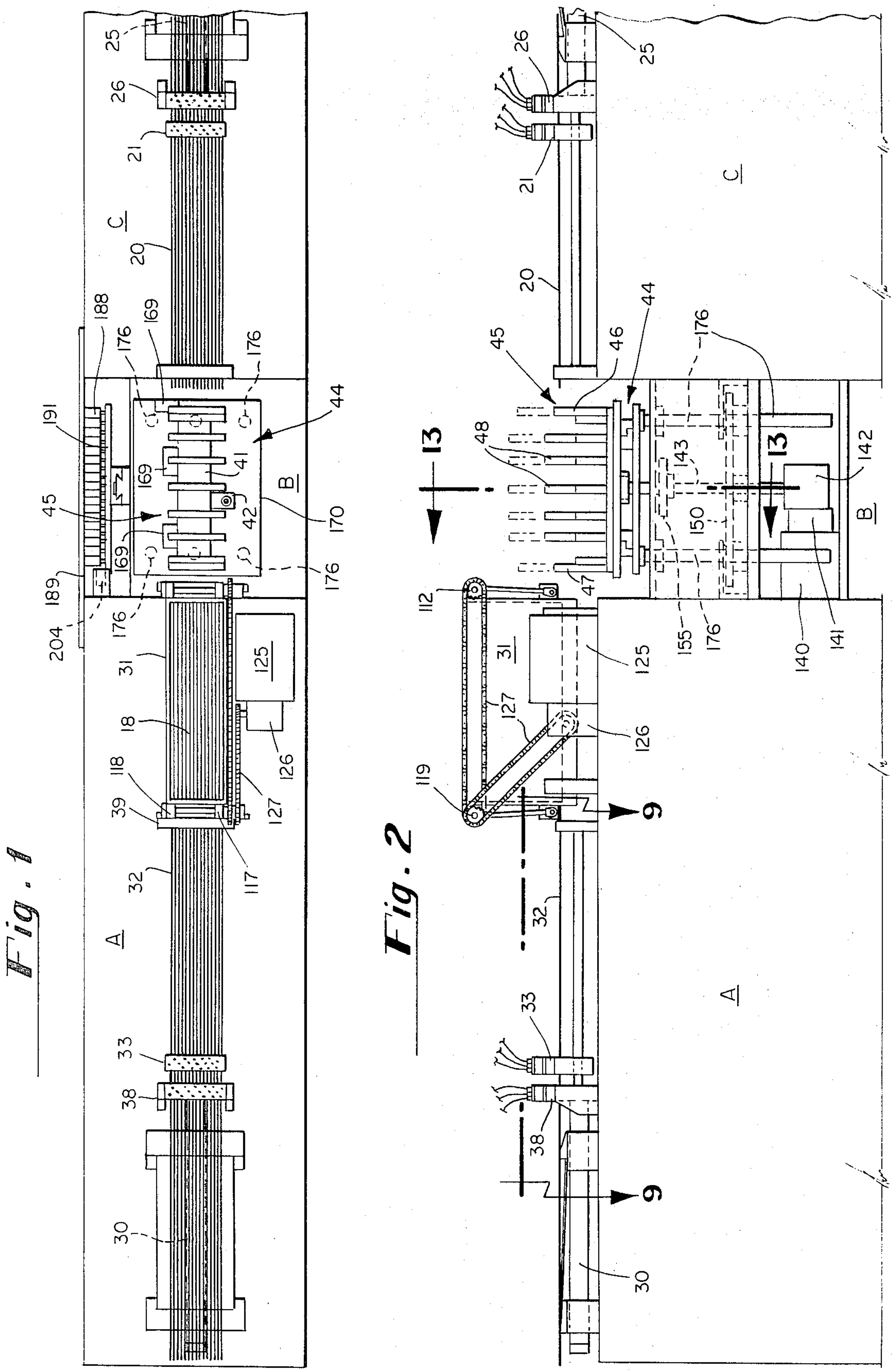


Fig. 1

Fig. 2

Patented Feb. 5, 1974 3,789,479

7 Sheets-Sheet 2

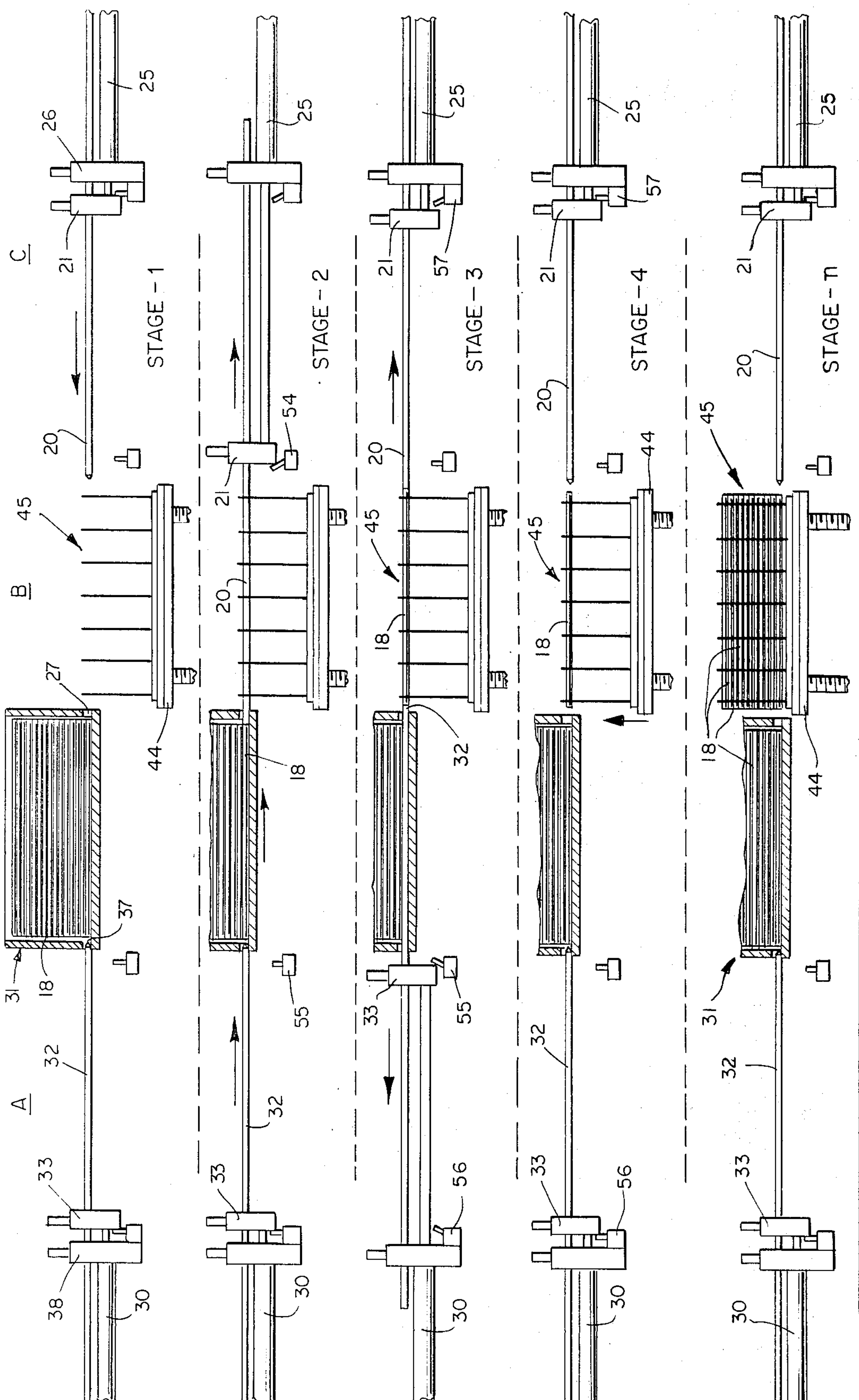


Fig. 3

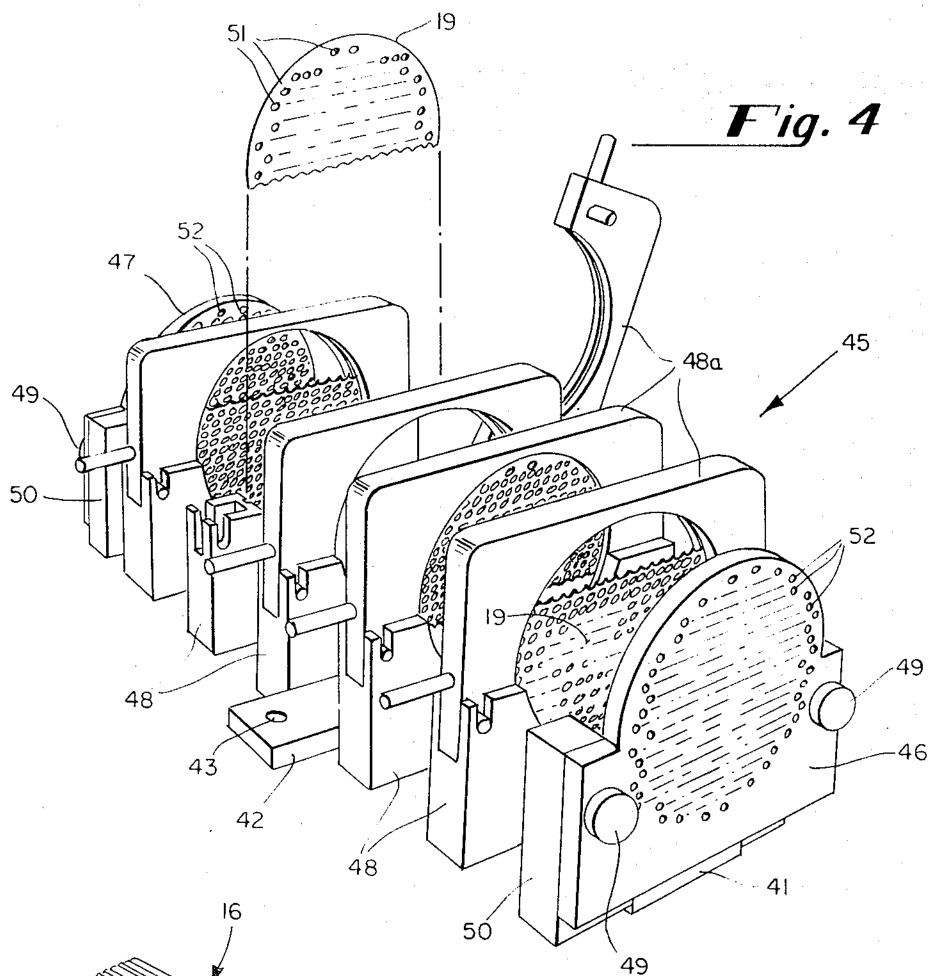


Fig. 4

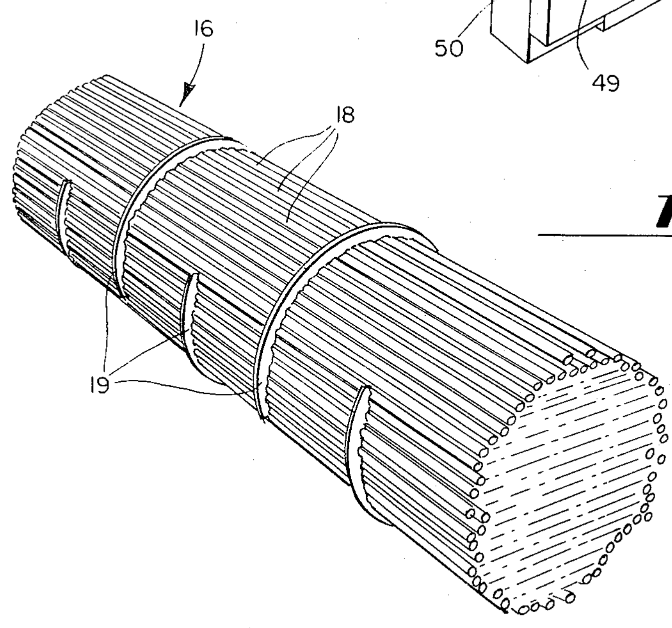


Fig. 5

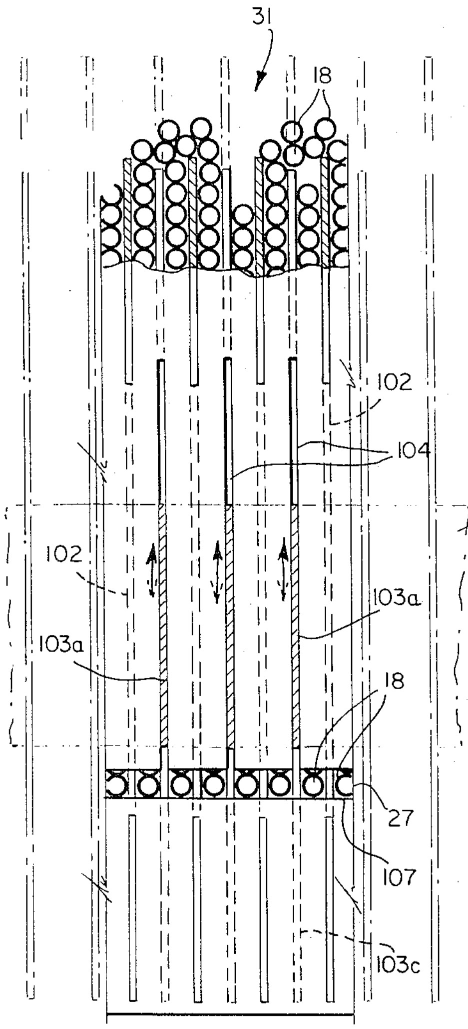


Fig. 15

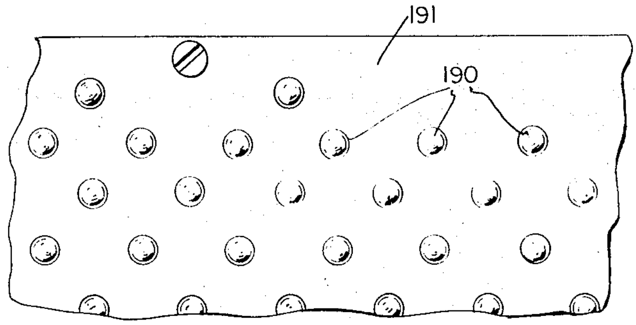


Fig. 16

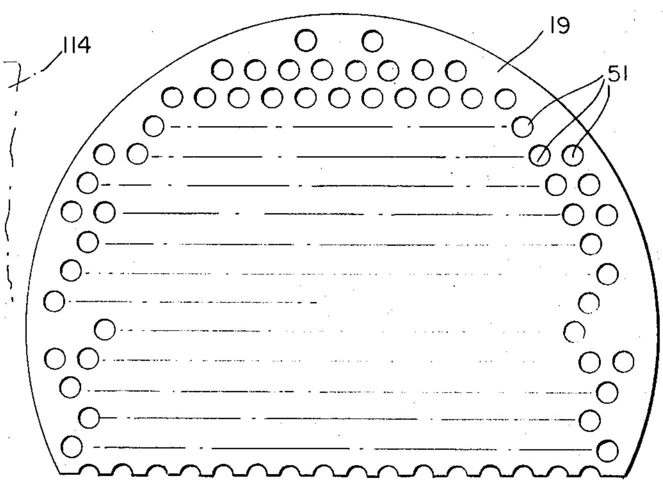
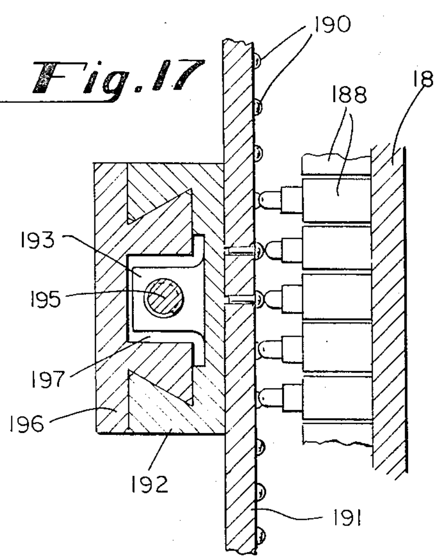


Fig. 6

Fig. 17



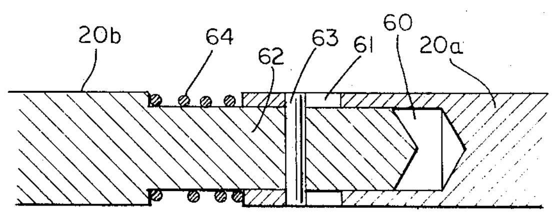


Fig. 8

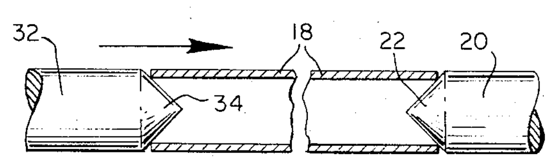


Fig. 7

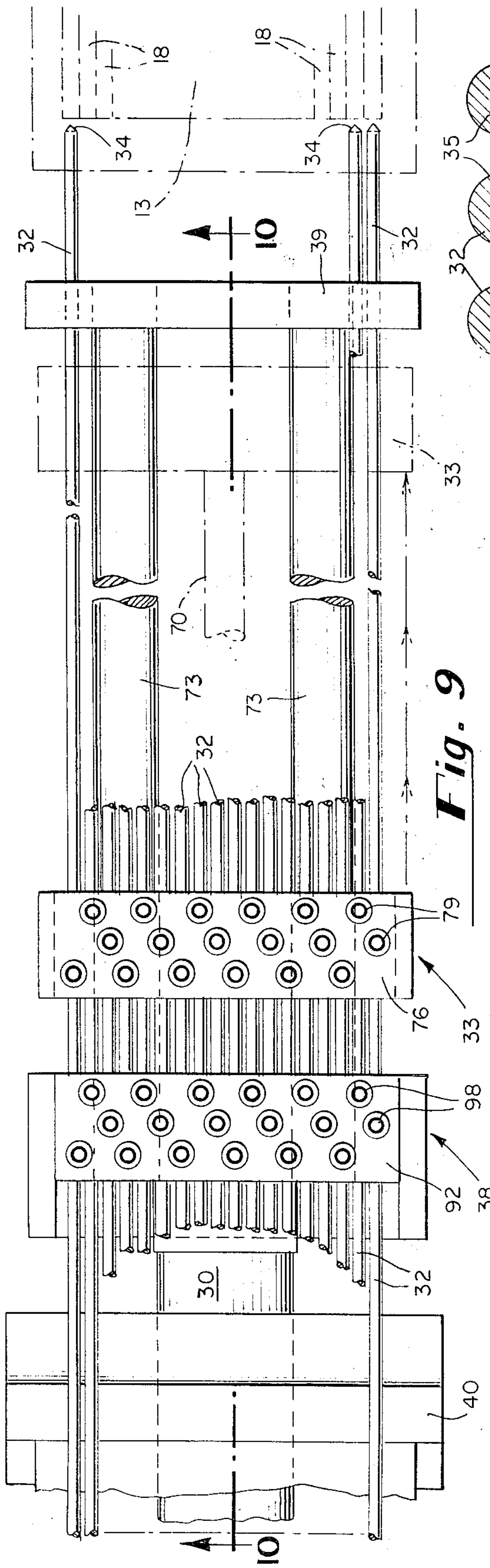


Fig. 9

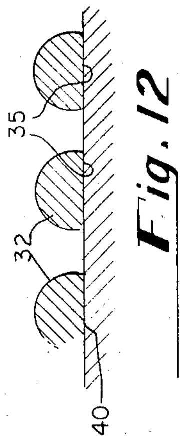


Fig. 12

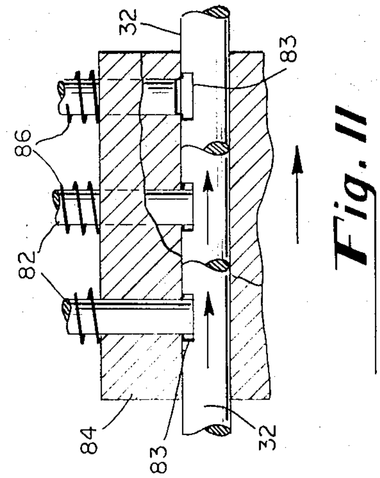


Fig. 11

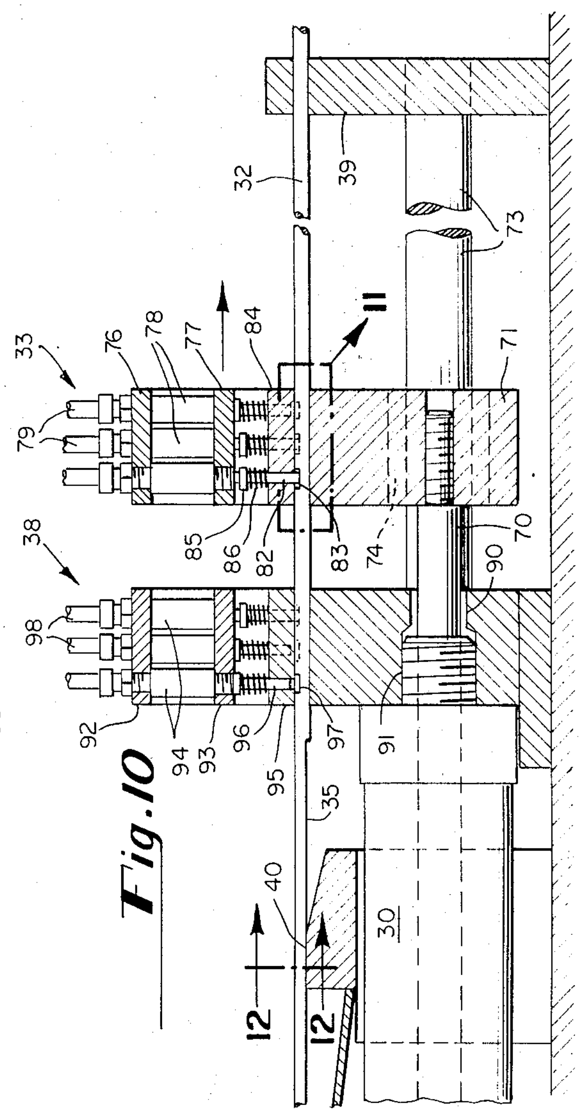
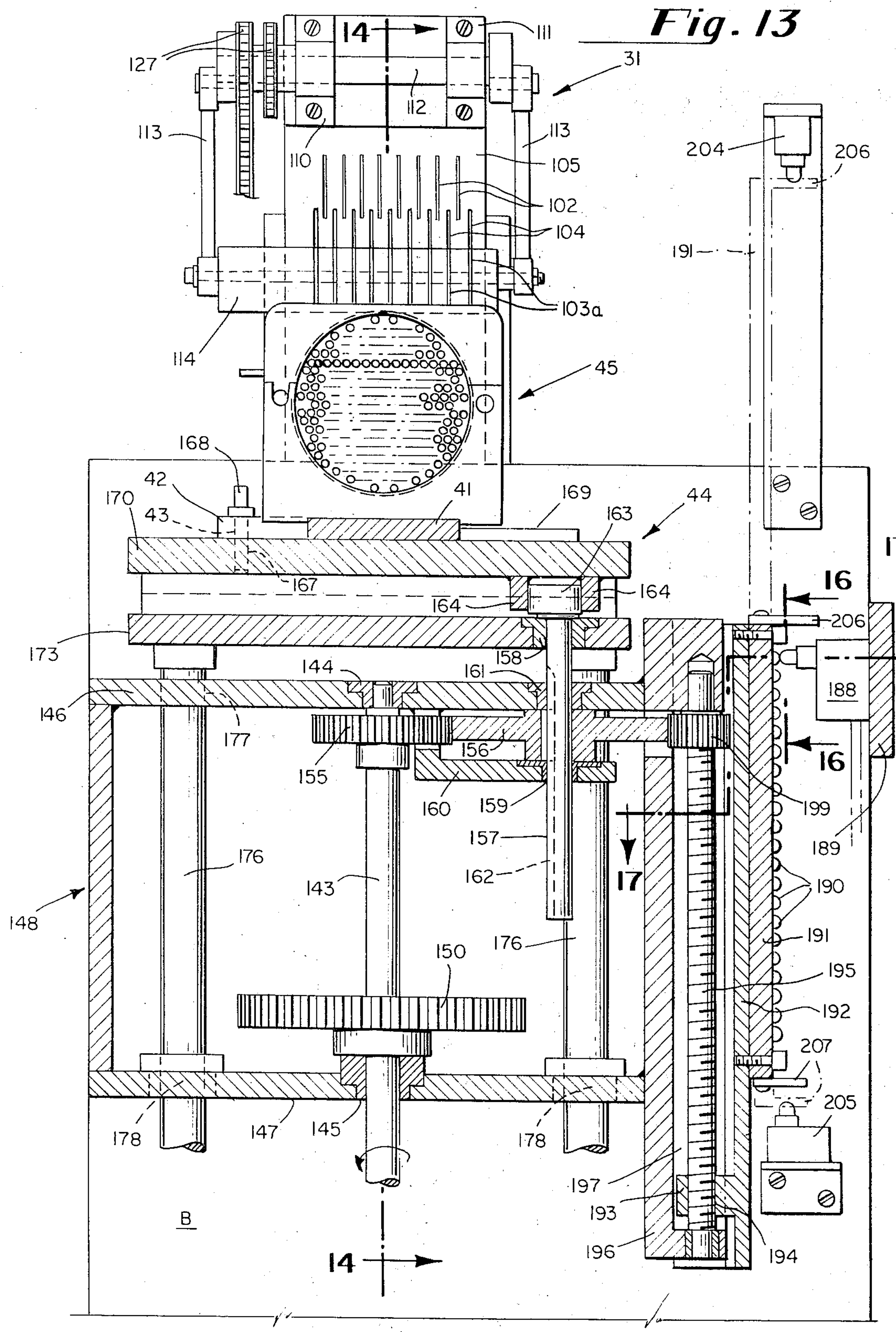


Fig. 10

Fig. 13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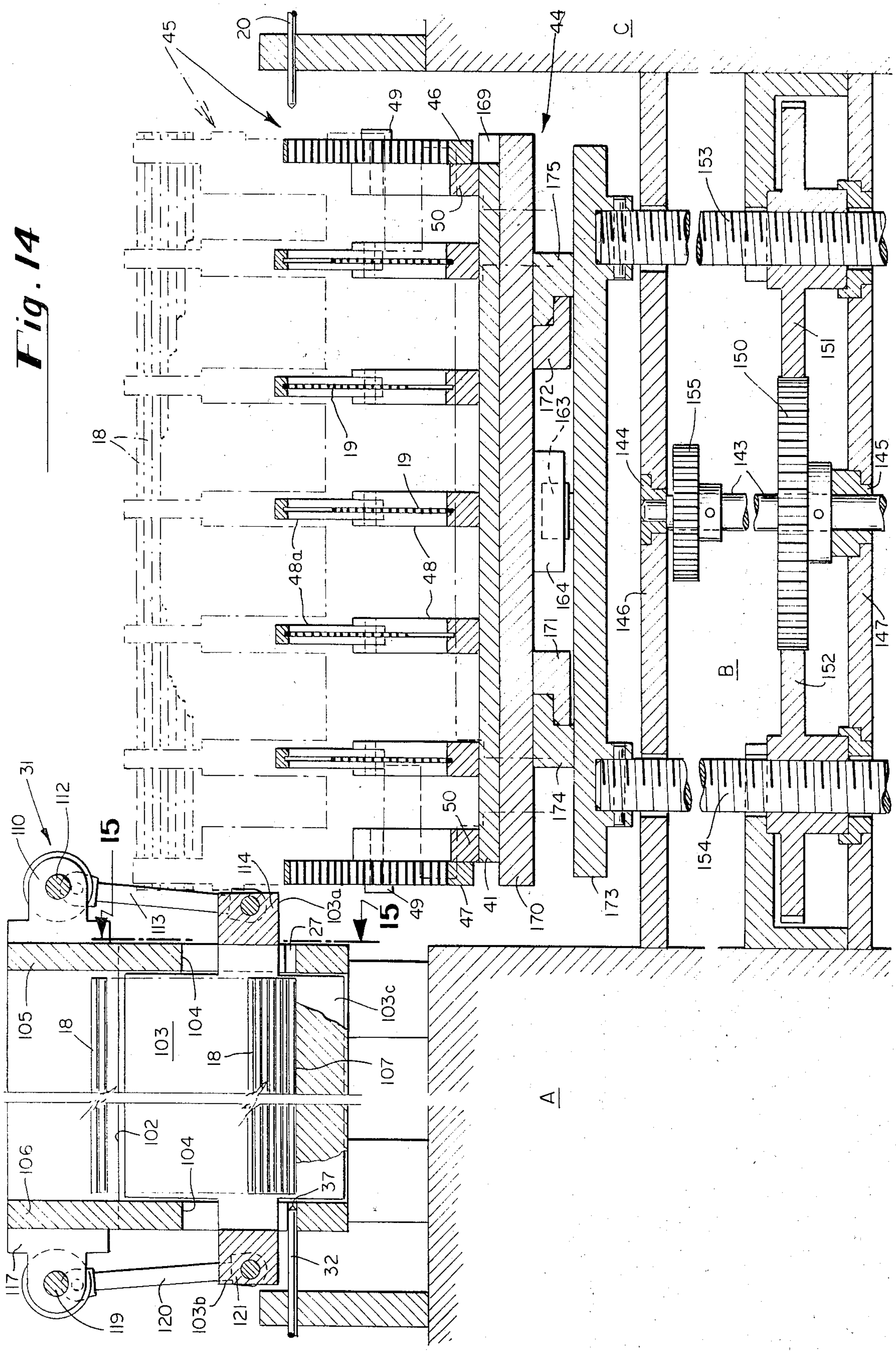
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103b
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Fig. 14

MACHINE FOR ASSEMBLING TUBES IN A HEAT EXCHANGER

SUMMARY OF THE INVENTION

The primary object of this invention is to provide a new and improved machine for assembling quickly and automatically the many individual tubes incorporated into a shell and tube type of heat exchanger. Attempts have been made in the past to develop automated machines and methods to accomplish this, but these efforts, apparently, have been only partially successful, if successful at all. To a large extent, the assembling of tubes in conventional shell and tube heat exchangers still is being carried out manually.

This invention for the first time, so far as is presently known, successfully provides an automated machine for assembling, quickly and completely, the tubes in such a heat exchanger. The invention, in its preferred form, contemplates a tube holding fixture mounted on a work table having capacity for vertical and horizontal movement, a supply of tubes, means for advancing successively selected quantities of tubes from the supply to the fixture, such means preferably comprising individually controlled guide and insertion rods, means for adjusting the work table vertically and horizontally, following each transfer of tubes, to prepare the fixture for the next delivery of tubes and, finally, suitable control means to ensure that proper quantities of tubes are deposited in the fixture throughout the assembly cycle and to stop the operation upon completion of the assembly.

DESCRIPTION OF THE VIEWS OF THE DRAWING

FIG. 1 is a fragmentary view in top plan of a preferred embodiment of the machine of this invention.

FIG. 2 is a fragmentary view in front elevation.

FIG. 3 is a schematic view in front elevation illustrating successive steps in the operation of the machine.

FIG. 4 is a fragmentary view in perspective of the tube holding fixture of the machine.

FIG. 5 is a fragmentary view in perspective of a completed tube assembly for a heat exchanger produced by the machine.

FIG. 6 shows one of the baffle plates of a tube assembly.

FIG. 7 is an enlarged, fragmentary view illustrating the manner in which a heat transfer tube is held by opposing rods as it is advanced to the tube holding fixture.

FIG. 8 is an enlarged, fragmentary view in section showing a preferred yielding connection between axially aligned rod sections.

FIG. 9 is an enlarged, fragmentary view looking in the direction of the arrows 9—9 of FIG. 2.

FIG. 10 is a fragmentary view in section looking in the direction of the arrows 10—10 of FIG. 9.

FIG. 11 is an enlarged, fragmentary illustration of the portion of FIG. 10 enclosed within the dot-dash lines designated 11.

FIG. 12 is an enlarged, fragmentary view in section looking in the direction of the arrows 12—12 of FIG. 10.

FIG. 13 is a fragmentary view in section looking in the direction of the arrows 13—13 of FIG. 2.

FIG. 14 is a fragmentary view in section looking in the direction of the arrows 14—14 of FIG. 13.

FIG. 15 is a fragmentary view in section looking in the direction of the arrows 15—15 of FIG. 14.

FIG. 16 is a fragmentary view of the control plate for the machine, looking in the direction of the arrows 16—16 of FIG. 13.

FIG. 17 is a fragmentary view in section looking in the direction of the arrows 17—17 of FIG. 13.

DETAILED DESCRIPTION OF THE INVENTION

Referring first to FIG. 5 there is illustrated a typical tube assembly 16 for a heat exchanger assembled by the machine of this invention. The assembly comprises a plurality of individual, elongated tubes 18, only a few of which are illustrated, and a plurality of spaced, perforated baffle plates 19 of usual construction. As is clearly shown in FIG. 6, the truncated baffle plates 19 each have a plurality of parallel rows of apertures 51 (only some of which are illustrated). The apertures of adjacent rows are disposed in staggered relationship to each other. The number of apertures in each row may vary widely.

Referring next to FIGS. 1, 2 and 3, the preferred machine of this invention may be conveniently divided into components A, B and C for ease of description. Component C includes a plurality of horizontally disposed guide rods 20, movable rod actuating means 21 for advancing a selected quantity of rods 20 past component B to a tube supply 31 in component A containing a quantity of tubes 18, a solenoid controlled double acting pneumatic cylinder 25 and a stationary detent mechanism 26 to prevent advancement of the non-selected rods.

Component A, in addition to tube supply 31, also includes a set of horizontally disposed insertion rods 32, movable rod actuating means 33 for advancing a selected quantity of rods 32 past the tube supply to component B and a solenoid controlled double acting pneumatic cylinder 30. The rods 20 and 32 are equal in number, and each individual rod 32 is aligned axially with a corresponding, opposing rod 20. Component A further includes a stationary detent mechanism 38 for preventing advance of the non-selected rods 32.

The tubes 18 in the tube supply 31 are disposed in successive horizontal layers, with their axes parallel to the axes of the rods 20 and 32. The horizontal axes of the tubes in the bottom layer are co-planar with the horizontal axes of rods 20 and 32. This is the "working plane" of the machine. Preferably, the number of tubes 18 in the bottom layer in hopper 31 equals the number of rods 20 (or 32), although the number of tubes could be greater or less than this number.

Component B includes a vertically and horizontally movable table 44 on which is mounted a tube holding fixture 45. As best shown in FIG. 4, fixture 45 includes a pair of axially spaced, transverse, vertical end plates 46, 47 and a plurality of intermediate transverse supports 48 for supporting vertically the baffle plates 19 of the tube assembly 16. Each of the intermediate supports 48 has its upper portion 48*a* hinged to provide for the insertion and removal of the baffle plates of the tube assemblies. The supports 48 sustain the baffle plates so that their rows of apertures 51 are horizontal.

The end plates 46, 47 of fixture 45 are provided with a plurality of staggered apertures 52 formed into several horizontal rows. The rows of apertures 52 of end plate 46 are co-planar with corresponding rows of apertures 52 of end plate 47 and with corresponding rows of apertures **51** of the upstanding intermediate baffle plates **19.** Each row of apertures **51, 52** in the same horizontal plane contains the same number of apertures, and each aperture of each row is aligned axially with a corresponding aperture in each of its other coplanar rows. Thus, each aperture **52** in the fixture end plate **46** is co-axial with a corresponding aperture in each of the upstanding baffle plates **19** and in end plate **47.**

The end plates **46, 47** are supported on table **44** so that their respective perforated areas are co-axial. Table **44** is vertically movable, both up and down, in successive increments, to bring the successive horizontal rows of staggered apertures **51, 52** into the "working plane," previously described, of the machine.

As will be explained in more detail, selected rods **20** and **32** are advanced and retracted, respectively, by the action of the pneumatic cylinders **25, 30** transmitted through the rod actuating means **21, 33.** FIG. **3** illustrates schematically various stages of operation of the machine. In stage **1**, the first step in assembling tubes **18** in fixture **45** is illustrated. A selected quantity of rods **20** is advanced, by rod advancing means **21** and pneumatic cylinder **25**, through the uppermost rows of axially aligned apertures **52, 51** in fixture **45** and baffle plates **19** to engage the proximate ends of the bottom layer of tubes **18** in hopper **31.**

As best shown in FIG. **7**, the forward ends **22** of the rods **20** preferably are of conical configuration, to permit limited entry of the rods into the open, proximate ends of the tubes **18.** The forward ends **34** of rod **32** are of similar conical configuration, to permit their partial entry into the opposite, open ends of tubes **18.** Hopper **31,** at each end, is provided with openings **27, 37** to permit the entry of rods **20, 32,** respectively, to engage the opposite ends of tubes **18,** in the manner illustrated in FIG. **7.**

Upon rods **20** reaching their maximum forward position, to engage tubes **18,** the rod advancing means **21** strikes a limit switch **54,** as illustrated in stage **2** of FIG. **3,** to cause the solenoid (not shown) to close off further flow of compressed air to pneumatic cylinder **25.** Activation of limit switch **54** also activates the solenoid controlled pneumatic cylinder **30** to advance those rods **32** which correspond to the selected rods **20.** This same selected quantity of rods **32** is advanced by rod advancing means **33** and pneumatic cylinder **30** to the bottom layer of tubes **18** in the hopper to engage and hold the tubes in the manner illustrated in FIG. **7.**

The rods **32** continue their advance, to push the corresponding rods **20** back beyond fixture **45** while, at the same time, advancing the selected tubes **18** to the fixture **45,** as illustrated by stage **3** of FIG. **3.** The tubes **18** are inserted by the rods **20, 32** through the axially aligned apertures **51, 52** in the uppermost row of apertures in end plates **46, 47** and baffles **19,** to complete the assembly of the first layer of tubes. When the rods **32** have advanced sufficiently to position properly the tubes **18** in fixture **45,** actuating means **33** strikes a limit switch **55.** This activates the cylinder solenoids (not shown) to reverse the flow of compressed air to cylinders **25, 30** to retract the selected rods **20, 32** to their original positions, as illustrated by stage **4** of FIG. **3.** The withdrawal of the rods **20, 32** completes the deposit of the first layer of tubes **18** in the fixture **45.**

Thereupon, as illustrated in stage **4** of FIG. **3,** table **44** is advanced upwardly an incremental distance sufficient to align the next succeeding co-planar rows of apertures **51, 52** in the working plane with the bottom layer of tubes **18** in hopper **31** and the rods **20, 32.** As the table **44** elevates, it also is adjusted horizontally to align axially the staggered apertures in the next succeeding rows with the rods **20, 32** and the tubes **18** in hopper **31.** This vertical and horizontal adjustment of table **44** occurs after rods **20, 32** have been restored to their normally retracted positions.

As rods **20** complete their return, rod actuating means **21** strikes a limit switch **57,** as shown in stage **4** of FIG. **3,** to shut off air to cylinder **25** and complete a circuit to activate suitable power control means to impart vertical and horizontal movement to table **44.** Similarly, as rods **32** complete their return, rod actuating means **33** strikes a limit switch **56** to shut off air to cylinder **30.**

In the particular embodiment shown (FIGS. **4, 5, 6**), there are two tubes **18** in the uppermost row of tubes of the assembly **16,** eight tubes in the second row, 11 in the third, etc. However, the number of arrangement of tubes in any heat exchanger tube assembly, or any row thereof, is a matter of choice.

Following each deposit of a selected number of tubes **18** in the fixture **45,** table **44** is advanced upwardly a distance sufficient to align each next succeeding coplanar rows of apertures **51, 52** in the working plane, until the last layer of tubes have been assembled, as illustrated by stage *n* of FIG. **3.** At this juncture, the tube assembly is ready for removal from the fixture **45,** preparatory to proceeding with the manufacture of the next assembly **16.**

Referring back, for a moment, to FIG. **4,** the newly completed tube assembly is removed from the fixture **45** by opening the hinged portions **48***a* of supports **48** and loosening bolts **49.** The latter secure the end plates **46, 47** to end plate supports **50,** and permit disengagement of the end plates from the opposite ends of the tubes **18** of the tube assembly.

In proceeding with the next tube assembly **16,** the machine cycle is reversed, with the first layer of tubes **18** being deposited by rods **20, 32** in the lowermost apertures **51, 52** of baffle plates **19** and fixture end plates **46, 47.** Following each deposit of tubes **18** in the fixture **45,** table **44** is lowered an incremental distance sufficient to align the next succeeding co-planar rows of apertures **51, 52** in the working plane. Thus, as table **44** gradually is lowered, the next tube assembly is prepared, until finally the uppermost horizontal rows of apertures **51, 52** have returned to the working plane. After the final deposit of tubes in the fixture, the tube assembly is removed and the machine made ready for the next operative cycle.

Each time table **44** is advanced upwardly or downwardly, preparatory to the deposit of a new row of tubes **18,** it is adjusted laterally to align properly the staggered apertures **51, 52** in the working plane with rods **20, 32** and the bottom layer of tubes **18** in hopper **31.**

In order to compensate for differences in tube length, and to provide for suitable flexibility in the system, each guide rod **22** may be divided into two axially aligned components **20***a* and **20***b* as shown in FIG. **8.** The forward component **20***a* has its rear end countersunk to provide a hole **60,** which is intercepted by a transverse slot **61.** The forward end **62** of the rear component **20***b* is reduced in diameter, to engage telescopically within hole **60**. A transverse pin **63**, force fitted into reduced end **62**, engages slot **61** to retain end **62** within hole **60**. Preferably, the length of pin **63** approximates the outside diameter of rod portion **20***a*. A coil spring **64** urges the rod components **20***a*, **20***b* apart, when the rod **20** is at rest in its normally retracted position, as shown in FIGS. **1** and **8**.

The insertion rods **32**, of course, may be similarly constructed.

Referring now to FIGS. **9–12**, a more detailed description of the structure and operation of the rod actuating means, rod detent mechanisms and pneumatic cylinders will be provided. Pneumatic cylinder **30** includes a reciprocal piston rod **70**, the external end portion of which is in threaded engagement with a vertically dependent portion **71** of actuating means **33** (FIG. **10**). As piston **70** is caused to advance and retract by the flow of compressed air to cylinder **30**, it causes actuating means **33** similarly to advance and retract, as illustrated in FIGS. **3** and **9**, along a pair of horizontally spaced guide rods **73**. The latter are engaged slidably by annular bushings **74** disposed within spaced bores formed in the dependent portion **71** of actuating means **33**.

Rod actuating means **33** is provided with a pair of vertically spaced, horizontal support members **76, 77** which extend tranversely of the rods **32**. The members **76, 77** support a plurality of vertical, staggered air clamps **78**, one of which is provided for each rod **32**. Each air clamp is a small pneumatic cylinder individually connected by a suitable conduit **79** to a source of compressed air (not shown). A suitable solenoid controlled valve (not shown) is interposed in each conduit **79**, to control individually the flow of compressed air to the air clamps **78**.

Each air clamp **78** is provided with a retractable plunger **82**, the distal end of which is adapted to engage within a notch **83** formed in the top of the rod **32** with which the air clamp is associated. A transverse guide bar **84** is disposed above rods **32** and is provided with a plurality of spaced, staggered bores, each for the reception of one of the plungers **82**. The plungers **82** are engaged slidably within the guide bar bores, for engagement with, and retraction from, the notches **83** in the rods **32**. Each plunger **82** is provided with a collar **85**. A coil spring **86** is disposed around each plunger between the collar and the top of the guide bar **84**. The springs **86** retract the plungers from the notches **83**, when compressed air is exhausted from the air clamps **78**. When the solenoid controlled valve (not shown) for any particular conduit **79** is opened, permitting compressed air to pass to the air clamp **78**, the plunger **82** advances against the force of the spring **86** to engage with notch **83**, and thereby clamp its rod **32** to the rod actuating means **33**. When this occurs, all rods **32** thus clamped to the rod actuating means **33** will advance when the pneumatic cylinder **30** causes actuating means **33** to advance, as previously explained, and as illustrated in FIG. **3**.

Rod detent mechanism **38** is fixed in place, by any suitable means, in component A of the machine. Its lower portion is provided with a bore **90**, to provide suitable clearance for piston rod **70**. Bore **90** is countersunk and threaded at **91**, to provide a support for the threaded forward end of pneumatic cylinder **30**. The upper portion of the detent mechanism **38** is provided with a structure similar to that of rod actuating means **33**. More specifically, there are provided vertically spaced transverse support members **92** and **93**, for supporting air clamps **94**, and a suitably apertured, transverse guide bar **95**. The air clamps **94** include spring-biased plungers **96** engagable within notches **97** formed in the top of the rods **32**. When flow of compressed air through conduits **98** to air clamps **94** is shut off, by suitable solenoid controlled valves (not shown), the plungers **96** are caused by their springs to retract from the notches **97** to the rods **32**.

Thus, each guide rod **32** is provided with a pair of spaced notches **83, 97** for reception of a plunger **82, 96**. By means of a suitable control system, to be explained in more detail hereinafter, one or the other of the plungers **82, 96** is engaged with its rod **32**, to clamp the latter either to rod actuating means **33** or rod detent mechanism **38**. When selected plungers **82** are engaged with their rods **32**, those rods will advance to fixture **45** (FIG. **3**, stages **2, 3**) when the rod actuating mechanism **33** is advanced. This occurs because the plungers **96** are retracted from the notches **97** of the selected rods **32**. However, those rods which remain clamped by their plungers **96** to the rod detent mechanism **38** do not advance with the rod actuating mechanism **33**. The plungers **82** of the latter rods are retracted from their notches **83** to ensure that the non-selected rods **32** remain clamped in their retracted position.

Preferably, rods **32** are of circular cross section, and are guided slidably within suitable bores provided in the rod actuating means **33**, the rod detent mechanism **38** and in support member **39** of component A of the machine (FIG. **10**). To prevent angular displacement of the rods **32**, which would disturb the alignment between the air clamp plungers and the notches in the rods, the rear portions of the rods **32** may be truncated at their bottoms **35** (FIGS. **10, 12**). A flat, horizontal support surface **40** may be provided to engage slidably with the flattened portions **35** of rods **32**, to prevent angular displacement of the latter.

The structure and operation of guide rods **20** and of actuating means **21**, rod detent mechanism **26** and pneumatic cylinder **25** for rods **20** are identical to that illustrated in FIGS. **9–12**.

Each new advance of probe rods **20** to the supply hopper **31** must be delayed for an interval sufficient to permit cpmpletion of the selection of the rods **20, 32** preparatory to the next delivery of tubes **18** to fixture **45**. This may be accomplished by any suitable means, such as a time delay relay in the circuit (not shown) which contains the solenoid controlling pneumatic cylinder **25**. More specifically, when rod actuating means **21** strikes limit switch **57**, upon the return of rods **20** to their normal position (FIG. **3**, stage **4**), switch **57** energizes the circuit to the solenoid (not shown) for pneumatic cylinder **25**, preparatory to the latter advancing the next selection of rods **20** to hopper **31**. A time delay relay (not shown) in this circuit delays the energization of the solenoid (and hence the activation of the cylinder **25**) sufficiently to permit completion of the selection of rods **20, 32** by the control system for the air clamps.

Turning now to FIGS. **13–15**, the structure of the tube supply hopper **31** will be described. Hopper **31** is open at the top, for feeding of tubes **18** thereto, and is provided with a plurality of stationary, uniformly spaced, vertical partitions **102**. Disposed midway between each adjacent pair of partitions **102** is a vertically movable partition **103.** The alternating partitions **102, 103** are parallel, and the spacing therebetween is uniform, to provide vertical slots for the reception of the tubes **18** deposited in the top of hopper **31.** The vertical slots provided by the alternating partitions **102, 103** are of a width just sufficient to accomodate the reception of a single tube **18,** but of a height sufficient to provide for a plurality of vertically stacked tubes, in the manner illustrated in FIG. **15.**

The moveable partitions **103** are each provided with front and rear extensions **103***a*, **103***b* which extend through elongated vertical slots **104** in the front and rear walls **105, 106** of hopper **31.** The partitions **103** are reciprocated vertically, as indicated by the arrows in FIG. **15.**

Reciprocatory motion is imparted to the movable partitions **103** by means of four cranks and a pair of spaced crankshafts. More particularly, secured to the upper portion of front wall **105** of hopper **31,** by suitable spaced brackets **110, 111,** is a rotatable, transverse crankshaft **112** on the opposite ends of which are suitably secured a pair of vertically dependent cranks **113** (FIG. **13**). The lower ends of the cranks **213** are secured, in any suitable manner, to a transverse beam **114.** Affixed to the beam **114,** at uniformly spaced intervals, are the extensions **103***a* of the movable partitions **103.**

Similarly, there is mounted on the rear wall **106** of hopper **31** a pair of spaced brackets **117, 118** for supporting crankshaft **119** (FIGS. **1, 14**). Mounted on the opposite ends of crankshaft **119** are a pair of vertically dependent cranks **120,** the lower ends of which are secured to a transverse beam **121.** The protruding extensions **103***b* of the vertically movable partitions **103** are affixed in uniformly spaced relation to the beam **121.**

Thus, rotation of crankshafts **112, 119** imparts a vertically reciprocal movement to the several partitions **103.** The effect of this motion is to provide uniform distribution, in successive horizontal layers, of the tubes **18,** in supply hopper **31,** as indicated schematically in FIG. **15.** The slots **104** in the front and rear walls **105, 106** of hopper **31** are elongated vertically, to accommodate the vertical movement of the partition extensions **103***a*, **103***b*. The movable partitions **103** are provided with vertically dependent portions **103***c* which extend below the floor **107** of supply hopper **31,** to ensure that, at all times, the individual tubes **18** in the bottom layer of tubes remain separated. The foregoing arrangement ensures that, at all times, there is a full complement of tubes **18** in the bottom layer of tubes in hopper **31,** preparatory to transfer of tubes to the fixture **45.**

As best shown in FIG. **2,** crankshafts **112, 119** are driven by an electric motor **125** through a suitable gear reduction unit **126** and a conventional sprocket chain and gear system **127.**

Referring now to FIGS. **1, 2, 13** and **14,** the detailed structure of the work table **44** and the means for imparting vertical and horizontal movement to it, now will be described. Table **44** includes a flat, horizontal plate **170** provided on its bottom with a pair of spaced, transverse, L-shaped track portions **171, 172** (FIG. **14**). Spaced below plate **170** is a second flat, horizontal plate **173** having a pair of spaced, transverse, L-shaped track portions **174, 175.** The track sections **171, 174** and **172, 175** are in slidably mating relationship to provide a pair of gibs, whereby upper plate **170** of table **44** may be moved transversely of the machine with respect to lower plate **173,** which is secured against transverse movement.

As shown in FIGS. **1, 4, 13, 14,** fixture **45** includes a bottom plate **41** on which the end plate supports **50** and the supports **48** are mounted. Support plate **41** is provided with a lateral extension **42** having a vertical bore **43.** The fixture **45** is retained in position on the top of plate **170** of table **44** by means of stop plates **169** disposed on one side of fixture support plate **41** and a vertical pin **168** engaged snugly within the bore **43** of extension **42** and a co-axial hole **167** in the top of plate **170.**

Affixed to the bottom of lower plate **173** adjacent each corner thereof (FIGS. **1, 13**) are four dependent guide rods **176.** The guide rods **176** are disposed slidably within co-axial apertures **177, 178** provided, respectively, in the horizontally spaced support plates **146, 147** of a support frame **148.** This arrangement permits plates **173, 170** of work table **44** to be moved vertically up and down with respect to the stationary support frame **148.**

Both horizontal and vertical movement is imparted to work table **44** by an electric motor **140** (FIG. **2**) acting through electric clutch **141,** indexing unit **142** and a vertical, rotatable, output shaft **143** extending upward from the indexing unit **142.** Shaft **143** is journalled in suitable bearings **144, 145** mounted, respectively, in the spaced support plates **146, 147** (FIG. **13**).

Affixed to vertical shaft **143,** above the top of plate **147,** is a spur gear **150** which meshes with and drives a pair of spaced gears **151, 152** (FIG. **14**). The driven gears **151, 152** are secured, respectively, to spaced vertical screws **153, 154** of reverse pitch, which are affixed to, and depend from, the bottom of lower plate **173** of work table **44.** Thus, when output shaft **143** is driven, gear **150** drives gears **151, 152** to turn vertical screws **153, 154** to raise or lower work table **44,** depending on the direction of rotation of motor **140.**

Affixed adjacent the top of shaft **143,** just below support **146** (FIG. **13**), is a pinion **155** which meshes with and drives a gear **156** mounted on a short, vertical shaft **157.** The shaft **157** is suspended from plate **173** and is journalled in a bearing **158** in plate **173,** in a bearing **161** in support plate **146** and in a bearing **159** in a support **160.** The support **160** may be affixed to and depend from the bottom of support plate **146** of support frame **148.**

Shaft **157** is provided with an elongated, axial keyway **162** which is engagable slidably with a key affixed to and extending internally of the bore of gear **156.** By reason of this construction, and by reason of being slidable axially with respect to bearings **159, 161** and gear **156,** shaft **157** is free to move vertically with work table **44.** Gear **156** is retained against vertical movement by the opposing surfaces of support plate **146** and support **160.** The upper portion of bearing **159** in support **160** is provided with a flanged portion to provide a horizontal bearing support for gear **156.**

The uppermost end of shaft **157** extends above the top of support plate **173,** and has mounted thereon an eccentric **163** snuggly disposed between the opposing surfaces of a pair of spaced, vertical ribs **164** which depend from the bottom of upper plate **170** of work table **44.** The ribs **164** are disposed axially of the machine (FIG. **14**) and hold the eccentric **163** captive. Thus, when angular movement is imparted to shaft **157**, by means of shaft **143** and gears **155, 156**, the upper plate **170** of work table **44** is caused to move in a horizontal plane transversely of the machine, the sliding engagement of the gibs **171, 174** and **172, 175**, making such movement possible, as previously explained.

Thus, motor **140**, acting through electric clutch **141**, indexing unit **142** and shaft **143** imparts vertical movement to work table **44** via gear **150**, and imparts horizontal movement to the table via gear **155**. Motor **140** runs continuously in one direction during each operative cycle of the machine, but is stopped automatically, as will be explained, upon the completion of each operative cycle. Electric clutch **141** preferably is of the "one revolution" type, whereby its intermittent energization is operative for a time interval sufficient to impart one full, intermittent revolution to shaft **143**.

More particularly, when limit switch **57** is activated by rod actuating means **21**, upon the return of rods **20** to their normal position (FIGS. **3**, stage **4**), a circuit to the electric clutch **141** is energized, thereby completing the driving connection between motor **140** and indexing unit **142**. This causes shaft **143** to turn or rotate one full revolution, whereupon the clutch is de-energized to terminate the driving connection between indexing unit **142** and motor **140**.

The ratio of gear **150** to driven gears **151, 152** may be **66:67**, whereby gears **151, 152** rotate slightly more than one full revolution during their intermittent, angular movement, to turn screws **153, 154** either to raise or lower the work table **144**, depending on the direction of rotation of shaft **143**. The pitch of the threads of screws **153, 154** and the relationship of the parts is such as to ensure that work table **44** is moved vertically an incremental distance sufficient to bring the succeeding rows of apertures **51, 52** in fixture **45** into the working plane of the machine.

The eccentric **163** rests on top of lower plate **173** of table **44** and hence it, together with its dependent shaft **157**, rises and falls with the vertical movement of table **44**. The ratio between gears **155, 156** preferably may be 2:1, whereby gear **156**, shaft **157** and eccentric **163** make one-half revolution for each complete revolution of gear **155**. The upper plate **170** of work table **44** is caused by eccentric **163** to reciprocate horizontally, transversely of the machine, upon vertical movement of the work table.

The shape of the eccentric **163** is such as to cause plate **170** of work table **44** to move through one complete unidirectional reciprocatory stroke during each half revolution of shaft **157**. The succeeding horizontal reciprocal strokes of plate **170** align axially the staggered apertures **51, 52** in the succeeding rows of apertures with the rods **20, 32** and the tubes **18** in the working plane of the machine, preparatory to the transfer of tubes from hopper **31** to fixture **45**.

Referring next to FIGS. **1, 13, 16** and **17**, the automatic controls for the machine now will be described. The controls include a plurality of microswitches **188** disposed horizontally on a fixed panel **189** supported in component B of the machine, adjacent the support frame **148** (FIG. **13**). The microswitches **188** are activated selectively by successive horizontal rows of knobs, buttons or similar protuberances **190** affixed to a vertically movable control plate **191**. As a comparison of FIGS. **6** and **16** illustrates, the knobs **190** correspond with the apertures **51** of the baffle plates **19**. Thus, like apertures **51**, knobs **190** are arranged in successive horizontal rows, with the knobs of adjacent rows disposed in staggered relationship to each other. For each row of apertures **51** (and **52**), there is a corresponding row of knobs **90**, and in the corresponding rows there are an equal number of apertures and knobs. The microswitches **188** are connected electrically to the solenoid controlled pneumatic valves (not shown) which control the flow of air to the air clamps for the rods **20, 32**. Each microswitch **188** is connected to an individual circuit which includes the solenoids (not shown) for each pair of air clamps **78, 94** for each insertion rod **32** and also for each pair of air clamps (not shown) for the corresponding guide rod **20**. Thus, when a particular microswitch **188** is activated by its knob **190**, it activates the four solenoids of its circuit to permit compressed air to flow to the corresponding air clamps of rod actuating means **21, 33** to clamp the selected rods **20, 32** preparatory to their activation while, at the same time, shutting off flow of compressed air to the corresponding air clamps of rod detent mechanisms **26, 38**, thereby permitting unclamping of those clamps from the selected rods **20, 32**. Thus, the combination of the knobs **190** on control plate **191** and the microswitches **188** is operative to select, through conventional electro-pneumatic means controlling the air clamps, for each incremental process step of the machine, precisely those guide rods **20** and insertion rods **32** necessary to be activated to transfer a selection of tubes **18** from hopper **31** to fixture **45**.

Control panel **191** is affixed to a vertically movable slide **192** (FIG. **13**) formed with a lateral extension **193** having a vertical, threaded bore **194** therein. Threadly engaged in bore **194** is an elongated vertical screw **195**.

The slide **192** dovetails in sliding engagement with a vertical guide **196** (FIG. **17**) affixed to the support frame **148** of the machine. A vertical, elongated opening **197** is formed in the guide **196** for reception of the vertical screw **195**. The opposite ends of screw **195** are supported rotatably in the guide **196** at each end of opening **197**. Thus, screw **195** is free to turn within opening **197** to impart vertical movement to the control panel **191** through threaded bore **194**. Affixed to the top of screw **195** is pinion **199** which meshes with, and is driven by, gear **156**. The ratio of gear **156** to pinion **199** may be 1:5, so that for each half revolution made by gear **156**, pinion **199** makes 2½ revolutions. Thus, the intermittent rotation of shaft **143**, transmitted through gears **155, 156, 199** to screw **195**, imparts intermittent vertical movement to control panel **191** relative to the microswitches **188**. The direction of rotation of motor **140**, and hence of shaft **143**, determines whether control panel moves up or down. Preferably, the arrangement is harmonized so that control panel **191** moves up when work table **44** moves up, and moves down when the table moves down.

The extent to which table **44** moves up and down, during each operative cycle of the machine, and the automatic shutting off of motor **140**, upon completion of each such cycle, is controlled by spaced microswitches **204, 205** mounted adjacent control panel **191** (FIG. **13**). The microswitches **204, 205** are activated, respectively, by spaced fingers **206, 207** mounted on control panel **191**.

More particularly, as table **44** and control panel **191** move up to complete an assembly of tubes in fixture **45**, finger **206** approaches microswitch **204**. Following the deposit of the last row of tubes in the fixture, the retraction of rod advancing means **21** activates microswitch **57** (FIG. **3**, stage **4**) to energize the electric clutch **141** to cause table **44** and panel **191** to move upward once again, whereupon finger **206** contracts microswitch **204**, as indicated by the shadow lines in FIG. **13.** This activation of switch **204** shuts off motor **140**, while, at the same time, reverses its polarity so that, when the motor is started again, it will reverse its direction of rotation to cause table **44** and control panel **191** to move downward during the next operative cycle of the machine.

Similarly, as table **44** and control panel **191** move downward, to complete an assembly of tubes in fixture **45**, finger **207** strikes microswitch **205**, as shown by the shadow lines in FIG. **13**, to shut off motor **140** and again reverse its polarity. Thus, when the motor again is started, it rotates in the reverse direction to move table **44** and control panel **191** upward.

Following each operative cycle of the machine, the motor **140** remains shut off, until the tube assembly **16** is removed from fixture **45**, and the fixture made ready for the next assembly. Thereupon, a conventional start button (not shown) is activated to start motor **140** and re-energize the circuits of the machine, for its next operative cycle.

The electrical circuitry of the machine is of conventional design, as are the various microswitches, solenoid actuated air valves (not shown), time delay relays (not shown), etc. employed therein, and form no part of this invention.

Although a preferred embodiment of this invention has been shown and described for the purpose of illustration, it is to be understood that various changes and modifications may be made therein without the parting from the spirit and utility of the invention, or the scope thereof as set forth in the appended claims.

We claim:

1. A machine for assembling automatically the tubes for a heat exchanger having a plurality of tubes and perforated baffle plates, said machine comprising:

1. a work table having capacity for vertical and horizontal movement,
2. a tube holding fixture mounted on the table, said fixture having:
   a. a pair of spaced, co-axial, perforated end plates, the respective perforations of which are disposed in successive rows, with each perforation of each end plate co-axial with a corresponding perforation in the other end plate, and
   b. at least one intermediate baffle plate supporting means,
   c. said baffle plate supporting means being operative to support perforated baffle plates with their perforations aligned axially with co-axial perforations of the end plates,
3. a tube supply adjacent to the table,
4. means associated with the tube supply for maintaining the tubes in successive horizontal layers,
5. a first plurality of horizontally disposed rods,
6. a second plurality of horizontally disposed rods,
7. said two sets of rods being mounted on opposite sides of the tube supply and having their individual rods aligned axially with corresponding rods of the other set,
8. means for actuating a selected quantity of rods of each set of rods to advance the same to the tube supply to withdraw therefrom a selected quantity of tubes and deposit said tubes in the fixture within axially aligned perforations,
9. control means for selecting a pre-determined quantity of rods of each set of rods preparatory to advancing the rods of the tube supply, and
10. table actuating means for changing automatically the position of the table relative to the tube supply following each successive deposit of tubes in the fixture.

2. A machine for assembling tubes for a heat exchanger comprising:

1. a table,
2. a tube holding fixture mounted on the table,
3. a tube supply adjacent to the table,
4. tube advancing means for advancing successively a selected quantity of tubes from the tube supply to the fixture, and
5. table actuating means for changing automatically the position of the table relative to the tube supply following each successive advance of tubes from the tube supply to the fixture, preparatory to the next advance of tubes to the fixture.

3. The machine of claim **2** wherein the tube advancing means comprises:

1. a first set of axially advanceable and retractable rods, and
2. a second set of axially advanceable and retractable rods,
3. said two sets of rods being disposed on opposite sides of the tube supply when in their most retracted position,
4. said two sets of rods being operative to advance selectively to the tube supply, withdraw a selected quantity of tubes therefrom and deposit the same in the tube holding fixture.

4. The machine of claim **3** wherein:

1. the rods of both sets of rods and at least some tubes of the tube supply are disposed in a common working plane of the machine,
2. the fixtures is provided with:
   a. a pair of spaced, co-axial, perforated end plates, the respective perforations of which are disposed in successive rows, with each perforation of each end plate co-axial with a corresponding perforation in the other end plate, and
   b. one or more intermediate baffle plate supporting means,
   c. said baffle plate supporting means being operative to support perforated baffe plates with their perforations aligned axially with co-axial perforations of the end plates, and
3. the table actuating means is operative automatically to position successive rows of said perforations in the working plane preparatory to each advance of tubes to the fixture.

5. The machine of claim **3** wherein rods of the first set of rods are aligned axially with rods of the second set.

6. The machine of claim **3** wherein:

1. each set of rods is disposed horizontally and
2. the table actuating means is operative to move the table vertically relative to the tube supply and the two sets of rods.

7. The machine of claim **6** further including means associated with the tube supply to maintain the tubes in successive horizontal layers.

8. The machine of claim **3** further including:
1. control means for selecting a pre-determined quantity of rods of each set of rods preparatory to advancing a selected quantity of tubes from the tube supply to the fixture following each movement of the table, and
2. rod actuating means for advancing the selected rods to and retracting said rods from the tube supply.

9. The machine of claim **8** wherein the fixture,
1. has a pair of spaced, co-axial, perforated end plates, the perforations of each plate being aligned axially with corresponding perforations of the other plate, and
2. includes one or more intermediate baffle plate supporting means,
3. said baffle plate supporting means being operative to support perforated baffle plates with their perforations aligned axially with co-axial perforations of the end plates.

10. The machine of claim **9,** wherein:
1. the rods of the two sets of rods are all disposed in the same axial plane,
2. the perforations of each fixture end plate are disposed in a plurality of successive co-planar rows and
3. the table actuating means is operative to position successive rows of perforations of both end plates in co-planar alignment with the two sets of rods, with one perforation of each co-planar row co-axial with one rod of each set of rods,
4. whereby, upon the advance of a selected quantity of tubes from the tube supply, said tubes are deposited in the fixture within axially aligned perforations.

11. The machine of claim **9** wherein:
1. the rods of both sets of rods and at least some of the tubes in the tube supply are disposed in a single working plane of the machine,
2. the perforations of each fixture end plate are disposed in a plurality of successive co-planar rows, and 3. the table actuating means, following each advance of tubes from the tube supply to the fixture, is operative automatically to move the table to locate the next successive co-planar rows of perforations of the fixture end plates in the working plane.

12. A machine for assembling automatically the tubes for a shell and tube type heat exchanger comprising:
1. a movable work table,
2. a perforated fixture mounted on the table,
3. a supply of tubes spaced from the fixture,
4. a plurality of individually controlled tube transfer devices for transmitting selected quanities fo tubes from the supply to the fixture for deposit within selected perforations in the fixture,
5. adjustment means for adjusting the table relative to the tube supply prior to each transmission of tubes to the fixture to position a selected quantity of perforations for reception of a selected quantity of transmitted tubes, and
6. actuating means for actuating selected quantities of the tube transfer devices in timed relation to each adjustment of the table.

13. The machine of claim **12** wherein:
1. the supply of tubes and the tube transfer devices are located in a common working plane of the machine, and
2. the table adjustment means positions a selected quantity of fixture perforations in the working plane prior to each transmission of tubes to the fixture.

14. A tube holding fixture for a machine for assembling tubes for a heat exchanger comprising:
1. a pair of spaced, co-axial, perforated end plates, the respective perforations of which are disposed in successive rows, with each perforation of each end plate co-axial with a corresponding perforation in the other end plate, and
2. at least one baffle plate support intermediate the end plates having a hinged member to permit insertion, clamping and removal of a baffle plate,
3. said baffle plate support being operative to support perforated baffle plates with their perforations aligned axially with co-axial perforations of the end plates.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,789,479 Dated February 5, 1974

Inventor(s) Morton F. Zifferer and Donald E. Flinchbaugh

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 40 "steps" should be --stages--.

Column 4, line 62 "22" should be --20--.

Column 5, line 17 after "piston" insert --rod--.

Column 6, line 10 "to" should be --of--.

Column 6 line 48 "completion" is misspelled.

Column 14, line 11 "of" is misspelled.

Signed and sealed this 24th day of September 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents